Chapter 7. Bioaccumulation of Contaminants in Fish Tissues

INTRODUCTION

Bottom dwelling (i.e., demersal) fishes are collected as part of the South Bay Ocean Outfall (SBOO) monitoring program to assess the accumulation of contaminants in their tissues. Anthropogenic inputs to the marine ecosystem (including municipal wastewater outfalls) can lead to increased concentrations of chemical contaminants within the local environment, and subsequently in the tissues of fishes and their prey. This is because the accumulation of contaminants in most fishes occurs through the biological uptake and retention of chemicals derived via various exposure pathways like the uptake of dissolved chemicals in seawater and the ingestion and assimilation of pollutants contained in different food sources (Rand 1995, USEPA 2000). In addition, demersal fishes may accumulate contaminants through ingestion of suspended particulates or sediments that contain pollutants because of their proximity to seafloor sediments. For this reason, the levels of many contaminants in the tissues of demersal fish are often related to those found in the environment (Schiff and Allen 1997), thus making these types of assessments useful in biomonitoring programs.

The bioaccumulation portion of the South Bay monitoring program consists of two components: (1) liver tissues are analyzed for trawl-caught fishes; (2) muscle tissues are analyzed for fishes collected by hook and line (rig fishing). Species of fish collected by trawling activities (see Chapter 6) are representative of the general demersal fish community, and certain species are targeted based on their prevalence in the community and therefore ecological significance. The chemical analysis of liver tissues in these fish is especially important for assessing population effects because this is the organ where contaminants typically concentrate (i.e., bioaccumulate). In contrast, fishes targeted for capture by rig fishing represent species that are characteristic of a typical sport fisher's catch, and are therefore considered of recreational and commercial importance and more directly relevant to human health concerns. Consequently, muscle tissue is analyzed from these fishes because it is the tissue most often consumed by humans, and therefore the results may have public health implications. All liver and muscle samples collected during the year are analyzed for contaminants as specified in the NPDES discharge permits that govern the SBOO monitoring program (see Chapter 1). Most of these contaminants are also sampled for the National Oceanic and Atmospheric Administration (NOAA) National Status and Trends Program. NOAA initiated this program to detect and monitor changes in the environmental quality of the nation's estuarine and coastal waters by tracking contaminants thought to be of environmental concern (Lauenstein and Cantillo 1993).

This chapter presents the results of all tissue analyses that were performed on fishes collected in the SBOO region during 2010. The goals of the chapter are to: (1) assess the level of contaminant loading in the fishes of the SBOO region, (2) identify possible effects of wastewater discharge on contaminants in fishes collected near the discharge site, and (3) identify any spatial or temporal trends in contaminant loading.

MATERIALS AND METHODS

Field Collection

Fishes were collected during April and October of 2010 at seven trawl and two rig fishing stations (Figure 7.1). California scorpionfish (*Scorpaena guttata*), English sole (*Parophrys vetulus*), hornyhead turbot (*Pleuronichthys verticalis*), and longfin sanddab (*Citharichthys xanthostigma*) were collected for analysis of liver tissues from the trawling stations, while California scorpionfish, brown rockfish (*Sebastes auriculatus*), copper rockfish (*Sebastes caurinus*), and vermilion rockfish (*Sebastes miniatus*) were collected for

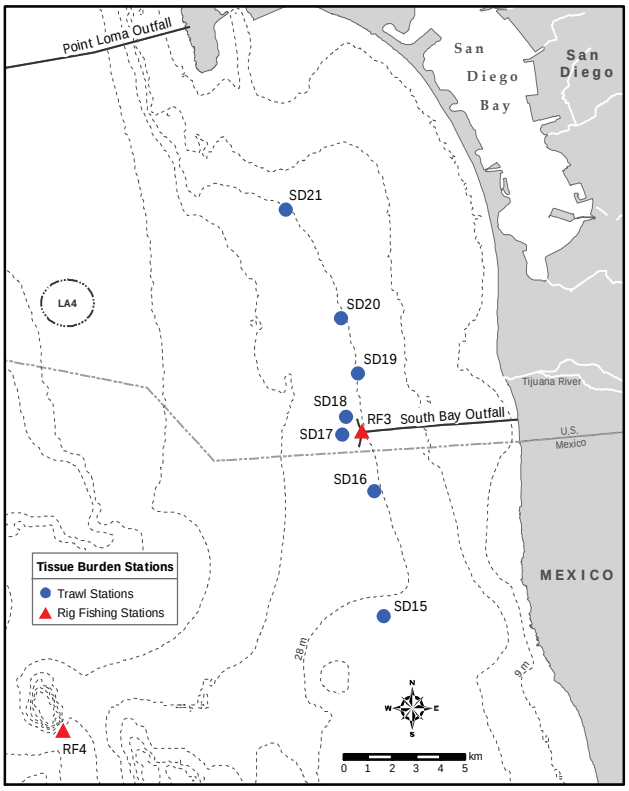

Figure 7.1
Otter trawl and rig fishing stations for the South Bay Ocean Outfall Monitoring Program.

analysis of muscle tissues at the two rig fishing stations (Table 7.1). All trawl-caught fishes were collected following City of San Diego guidelines (see Chapter 6 for a description of collection methods). Efforts to collect the targeted fish species at the trawl stations were limited to five 10-minute (bottom time) trawls per site. Fishes collected at the two rig fishing stations were caught within 1 km of the station location using standard rod and reel procedures; fishing effort was limited to 5 hours at each of these stations. Occasionally, insufficient numbers of the target species were obtained despite this effort, thus resulting in reduced number of composite samples at a particular station.

In order to facilitate the collection of sufficient tissue for subsequent chemical analysis, only fish $\geq$13 cm in standard length were retained. These fish were sorted into three composite samples per station, with each composite containing a minimum of three individuals. Composite samples were typically made up of a single species; the only exceptions were samples that consisted of mixed species of rockfish as indicated in Table 7.1. All fish collected were wrapped in aluminum foil, labeled, sealed in re-sealable plastic bags, placed on dry ice, and then transported to the City's Marine Biology Laboratory where they were held in the freezer at -80°C until dissection and tissue processing.

Tissue Processing and Chemical Analyses

All dissections were performed according to standard techniques for tissue analysis. A brief summary follows, but see City of San Diego (2004) for additional details. Prior to dissection, each fish was partially defrosted and then cleaned with a paper towel to remove loose scales and excess mucus. The standard length (cm) and weight (g) of each fish were recorded (Appendix F.1). Dissections were carried out on Teflon® pads that were cleaned between samples. The tissues (liver or muscle) from each dissected fish were then placed in separate glass jars for each composite sample, sealed, labeled, and stored in a freezer at -20°C prior to chemical analyses. All samples were subsequently delivered to the City's Wastewater Chemistry Services Laboratory for analysis within 10 days of dissection.

Chemical constituents were measured on a wet weight basis, and included trace metals, DDT and other chlorinated pesticides, polychlorinated biphenyl compounds (PCBs), and polycyclic aromatic hydrocarbons (PAHs) (see Appendix F.2 for full listing and chemical abbreviations). Metals were measured in units of milligrams/kilogram tissue and are expressed herein as parts per million (ppm), while pesticides, PCBs, and PAHs were measured as micrograms/kilogram tissue and expressed as parts per billion (ppb). The data for each parameter reported herein were generally limited to values above method detection limits (MDL). However, concentrations below MDLs were included as estimated values if the presence of the specific constituent was verified

Table 7.1

Species of fish collected from each SBOO trawl and rig fishing station during April and October 2010.

Survey	Station	Composite 1	Composite 2	Composite 3
April 2010	RF3	Brown rockfish	Brown rockfish	Mixed rockfish[a]
	RF4	California scorpionfish	California scorpionfish	California scorpionfish
	SD15	No sample[b]	No sample[b]	No sample[b]
	SD16	English sole	No sample[b]	No sample[b]
	SD17	English sole	Longfin sanddab	Hornyhead turbot
	SD18	English sole	English sole	Hornyhead turbot
	SD19	Longfin sanddab	English sole	Hornyhead turbot
	SD20	Hornyhead turbot	Hornyhead turbot	English sole
	SD21	Hornyhead turbot	Hornyhead turbot	English sole
October 2010	RF3	Brown rockfish	Brown rockfish	Brown rockfish
	RF4	California scorpionfish	California scorpionfish	California scorpionfish
	SD15	Hornyhead turbot	English sole	California scorpionfish
	SD16	Longfin sanddab	English sole	Longfin sanddab
	SD17	Longfin sanddab	Longfin sanddab	Hornyhead turbot
	SD18	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD19	Longfin sanddab	Longfin sanddab	Longfin sanddab
	SD20	Longfin sanddab	Longfin sanddab	No sample[b]
	SD21	Longfin sanddab	Longfin sanddab	Hornyhead turbot

[a] Includes vermilion and copper rockfish; [b] Insufficient fish collected (see text)

by mass-spectrometry (i.e., spectral peaks confirmed). A more detailed description of the analytical protocols is provided by the Wastewater Chemistry Services Laboratory (City of San Diego 2011).

Data Analyses

Data summaries for each contaminant include detection rates (i.e., number of reported values/ number of samples), minimum, maximum, and mean detected values of each parameter by species. Totals for DDT, PCBs, and PAHs were calculated for each sample as the sum of the detected constituents. For example, total DDT (tDDT) equals the sum of all DDT derivatives while total PCB (tPCB) equals the sum of all congeners. The detected values for each of these individual constituents are listed in Appendix F.3. In addition, the distribution of frequently detected contaminants in fishes collected in the SBOO region was assessed by comparing concentrations in fishes collected at "nearfield" stations located within 1000 m of the SBOO (SD17, SD18, RF3) to those from "farfield" stations located farther away to the south (SD15, SD16), north (SD19–SD21), and west (RF4). Concentrations were also compared to values detected during the pre-discharge period when available. Because concentrations of contaminants can vary so much among different species of fish, only intra-species comparisons were used for these evaluations.

Finally, in order to address seafood safety and public health issues, the concentrations of contaminants found in fish muscle tissue samples collected in 2010 were compared to state, national, and international limits and standards. These include: (1) the California Office of Environmental Health Hazard Assessment (OEHHA), which has developed fish contaminant goals for chlordane, DDT, methylmercury, selenium, and PCBs (Klasing and Brodberg 2008); (2) the United States Food and Drug Administration (USFDA), which has set limits on the amount of mercury, total DDT, and chlordane in seafood that is to be sold for human consumption (Mearns et al. 1991); and (3) international standards

for acceptable concentrations of various metals and DDT (Mearns et al. 1991).

Results

Contaminants in Trawl-Caught Fishes

Metals

Eleven metals occurred in ≥70% of the liver samples analyzed from trawl-caught fishes in the SBOO region during 2010, including aluminum, arsenic, cadmium, chromium, copper, iron, manganese, mercury, selenium, silver, and zinc (Table 7.2). Another seven metals (i.e., antimony, barium, beryllium, lead, nickel, thallium, tin) were also detected, but less frequently at rates between 3–65%. During 2010, several metals were found at levels that exceeded pre-discharge values (Figure 7.2). These included aluminum, arsenic, cadmium and mercury, which exceeded pre-discharge values in 28–47% of the samples, and copper, iron, manganese, selenium and zinc, which exceeded pre-discharge values in ≤11% of the samples. Most of these exceedances occurred in English sole and hornyhead turbot samples, and despite being higher than pre-discharge values, had low concentrations overall (e.g., <40 ppm over all species for 15 of the 18 metals).

Several metals occurred in concentrations that varied greatly among the different species of fish (Table 7.2). For example, the highest values of antimony, cadmium, copper, lead, mercury, nickel, selenium, silver, and thallium occurred in samples of longfin sanddab. In contrast, the highest concentrations of aluminum, barium, beryllium, chromium, manganese and zinc occurred in samples of hornyhead turbot, while the highest concentrations of arsenic, iron and tin were detected in samples of English sole. The only liver sample collected from a California scorpionfish during 2010 generally contained low concentrations of metals.

Intra-species comparisons between nearfield and farfield stations suggest that there was no clear relationship between contaminant loads in fish liver tissues and proximity to the outfall (Figure 7.2). In most cases, relatively high concentrations occurred throughout the region and showed no pattern relative to the outfall. However, the maximum values of arsenic, cadmium, and selenium in longfin sanddab liver tissues all occurred in a sample collected from outfall station SD17.

Pesticides

Two chlorinated pesticides were detected in fish liver tissues during 2010 (Table 7.3). DDT was found in every tissue sample with tDDT concentrations ranging from 9 to 300 ppb. The most frequently detected DDT derivative was p,p-DDE, which was found in 100% of these samples at concentrations up to 270 ppb (Appendix F.3). Additional DDT derivatives detected in more than 50% of the samples included o,p-DDE, p,p-DDD, and p,p-DDMU. The other pesticide detected in fish tissues during the past year, hexachlorobenzene (HCB), occurred in 64% of the samples at concentrations up to 5.9 ppb.

All DDT concentrations were below the maximum levels detected in the same species prior to wastewater discharge (Figure 7.3). HCB was not detected frequently during the pre-discharge period because of substantially higher detection limits. Overall, there were no clear relationships between concentrations of either DDT or HCB in fish tissues and proximity to the outfall (Figure 7.3).

PAHs and PCBs

PAHs were detected in a single longfin sanddab liver sample during 2010, at a concentration of 41.9 ppb (Table 7.3). In contrast, PCBs occurred in every tissue sample. PCB 138 and PCB 153/168 were the most frequently detected congeners in liver tissues as they were found in every sample; other frequently detected congeners (i.e., >50%) included PCB 66, PCB 70, PCB 74, PCB 99, PCB 101, PCB 118, PCB 149, PCB 180, PCB 183, PCB 187, and PCB 194 (Appendix F.3). Total PCB concentrations were highly variable in South Bay fish tissues, ranging from 4.4 to 465.9 ppb (Table 7.3). These concentrations were less than pre-discharge values, with no clear relationship with proximity to the outfall (Figure 7.3).

Table 7.2

Summary of metals in liver tissues of fishes collected at SBOO trawl stations during 2010. Data include the number of detected values (*n*), minimum, maximum and mean* detected concentrations per species, and the detection rate and max value for all species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses. See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Ti	Sn	Zn
California scorpionfish																		
n (out of 1)	1	0	1	1	0	1	1	1	1	0	1	1	0	1	1	0	0	1
Min	7.2	nd	0.7	0.033	nd	0.99	0.114	6.8	36.1	nd	0.54	0.070	nd	0.80	0.111	nd	nd	50.7
Max	7.2	nd	0.7	0.033	nd	0.99	0.114	6.8	36.1	nd	0.54	0.070	nd	0.80	0.111	nd	n	50.7
Mean	7.2	—	0.7	0.033	—	0.99	0.114	6.8	36.1	—	0.54	0.070	—	0.80	0.111	—	—	50.7
English sole																		
n (out of 9)	8	0	9	0	0	9	7	9	9	7	9	9	0	9	9	2	5	9
Min	nd	nd	2.5	nd	nd	0.63	nd	3.5	72.7	nd	0.76	0.020	nd	1.05	0.103	nd	nd	23.6
Max	7.4	nd	35.6	nd	nd	2.38	0.192	9.3	319.0	3.110	1.74	0.134	nd	3.07	0.447	0.573	0.567	79.4
Mean	5.8	—	16.6	—	—	1.57	0.143	6.9	192.4	1.206	1.40	0.090	—	2.08	0.207	0.532	0.342	40.4
Hornyhead turbot																		
n (out of 10)	8	0	10	3	1	10	8	10	10	0	10	10	0	10	10	3	6	10
Min	nd	nd	2.5	nd	nd	4.40	nd	5.5	34.1	nd	0.97	0.068	nd	0.58	0.140	nd	nd	34.7
Max	163.0	nd	5.9	0.169	0.009	8.37	0.237	11.0	69.8	nd	2.74	0.177	nd	1.59	0.268	0.632	0.286	88.5
Mean	47.3	—	4.1	0.126	0.009	6.56	0.156	8.0	52.4	—	1.74	0.128	—	1.08	0.210	0.558	0.240	49.6
Longfin sanddab																		
n (out of 16)	15	8	16	6	0	16	11	16	16	2	16	16	6	16	16	13	11	16
Min	nd	nd	3.8	nd	nd	1.48	nd	5.7	49.8	nd	0.90	0.051	nd	0.76	0.077	nd	nd	20.8
Max	9.7	0.433	18.7	0.074	nd	8.99	0.160	13.8	250.0	0.376	1.82	0.279	0.256	3.23	0.481	0.870	0.440	35.9
Mean	7.1	0.304	6.9	0.047	—	3.33	0.141	8.1	94.5	0.366	1.18	0.103	0.224	1.25	0.247	0.602	0.319	26.4
All Species:																		
Detection Rate (%)	89	22	100	28	3	100	75	100	100	25	100	100	17	100	100	50	61	100
Max Value	163.0	0.433	35.6	0.169	0.009	8.99	0.237	13.8	319.0	3.110	2.74	0.279	0.256	3.23	0.481	0.870	0.567	88.5

* Minimum and maximum values were calculated based on all samples, whereas means were calculated on detected values only.

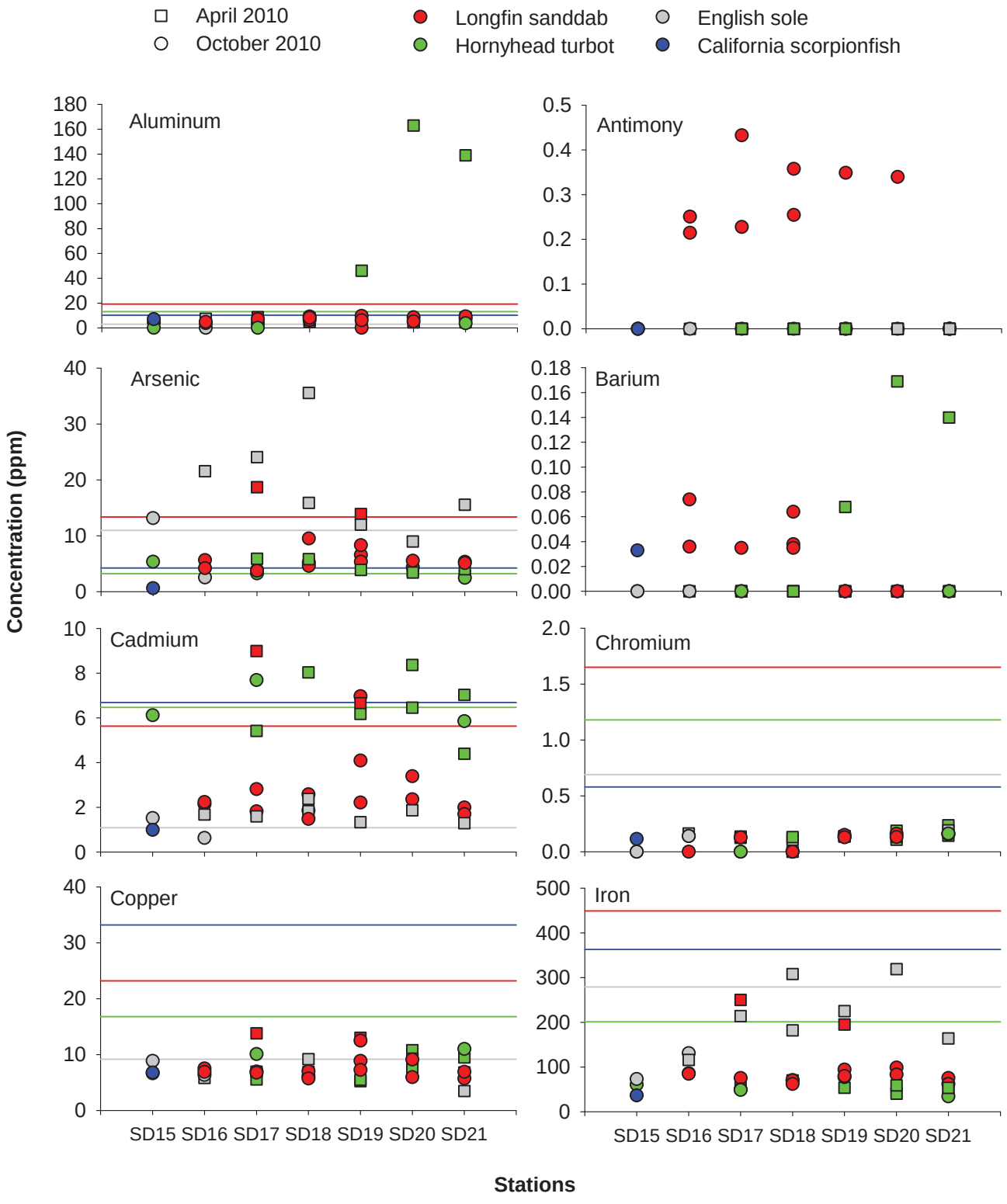

Figure 7.2

Concentrations of metals detected in more than 20% of liver tissues of fishes collected from each SBOO trawl station during 2010. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; missing lines indicate metals were not detected in that species pre-discharge because of substantially higher detection limits. To differentiate between missing values (i.e., samples that were not collected or not analyzed; see Table 7.1) and non-detects, zeros were added as placeholders for non-detected values. Stations SD17 and SD18 are considered “nearfield” (see text).

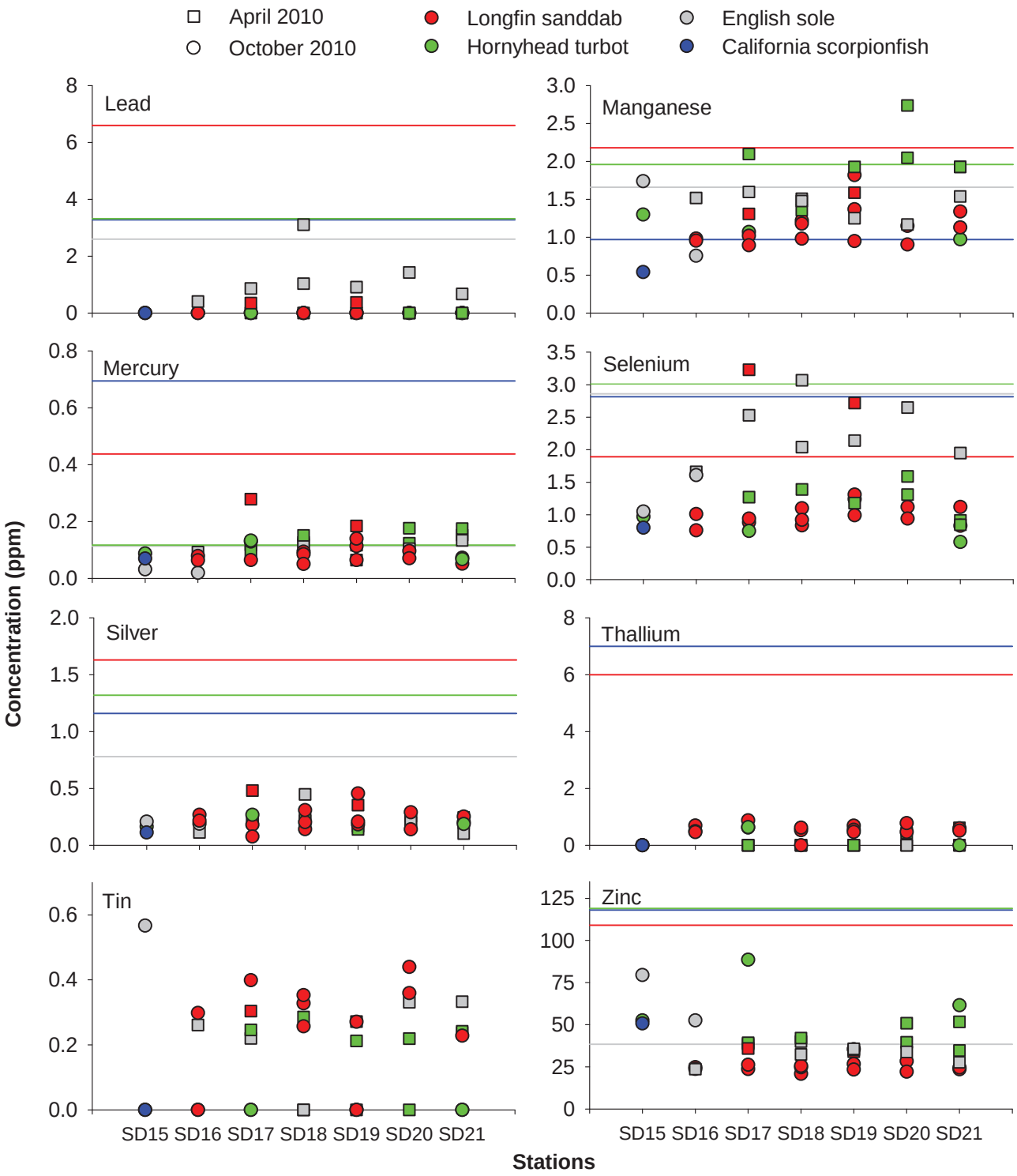

Figure 7.2 *continued*

Contaminants in Fishes Collected by Rig Fishing

Arsenic, copper, mercury, selenium, and zinc occurred in 100% of the muscle tissue samples collected from the two rig fishing stations in 2010 (Table 7.4). Aluminum and thallium were only detected in 50–58% of the samples, while barium, beryllium, chromium, iron, lead and tin were detected in 33% or less of the samples. Antimony, cadmium, manganese, nickel and silver were never detected. The metals present in the highest concentrations were aluminum (up to 11.5 ppm),

zinc (up to 6.3 ppm), arsenic (up to 3.4 ppm), and iron (up to 2.7 ppm). Overall, concentrations of these contaminants were fairly similar between each rig fishing station and occurred in concentrations less than those measured in the same species prior to discharge (Figure 7.4). Exceptions to this included aluminum, arsenic, mercury and zinc, each of which exceeded pre-discharge maxima in at least one sample (out of 12 total), primarily at station RF4.

Total DDT, composed primarily of p,p-DDE, was detected in 100% of the muscle samples, while the pesticide HCB was detected in only 33% (Table 7.5). Concentrations of pesticides ranged from < 1 ppb for HCB to 17.8 ppb for tDDT. These concentrations were less than pre-discharge values, with no clear relationship with proximity to the outfall (Figure 7.3). PCBs were detected in 92% of the muscle samples, at concentrations up to 12.3 ppb. The congener PCB 153/168 was the most frequently detected, occurring in every muscle sample containing PCBs, while another 20 congeners were detected in ≤42% of the samples (Appendix F.3).

Most of the contaminants detected in fish muscle tissues in 2010 occurred at concentrations below state, national, and international limits and standards (Tables 7.4, 7.5). Only arsenic and selenium were detected in concentrations higher than median international standards, while mercury (as a proxy for methylmercury) and tPCB exceeded OEHHA fish contaminant goals. Exceedances for arsenic occurred in both California scorpionfish and mixed rockfish muscle samples, while exceedances for selenium occurred in scorpionfish, mixed rockfish, and brown rockfish. The exceedances for mercury were detected in both brown rockfish and California scorpionfish, while the exceedances for tPCB occurred only in scorpionfish.

Table 7.3

Summary of pesticides, tPCB, tPAH, and lipids in liver tissues of fishes collected at SBOO trawl stations during 2010. Data include the number of detected values (*n*), minimum, maximum, and mean* detected concentrations for each species, and the detection rate and max value for all species. Data are expressed in ppb for all parameters except lipids, which are presented as % weight; the number of samples per species is indicated in parentheses; See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for tDDT, tPCB, and tPAH.

	Pesticides				
	HCB	tDDT	tPCB	tPAH	Lipids
California scorpionfish					
n (out of 1)	0	1	1	0	1
Min	nd	78	98.0	nd	14.2
Max	nd	78	98.0	nd	14.2
Mean	—	78	98.0	—	14.2
English sole					
n (out of 9)	6	9	9	0	9
Min	nd	11	24.5	nd	0.5
Max	5.9	300	123.8	nd	21.1
Mean	3.0	100	56.7	—	7.8
Hornyhead turbot					
n (out of 10)	2	10	10	0	10
Min	nd	9	4.4	nd	2.9
Max	2.5	104	40.6	nd	11.0
Mean	2.3	54	25.8	—	6.3
Longfin sanddab					
n (out of 16)	15	16	16	1	16
Min	nd	70	82.0	nd	6.5
Max	5.0	287	465.9	41.9	39.2
Mean	3.9	172	232.0	41.9	26.0
All Species:					
Detection Rate (%)	64	100	100	3	100
Max Value	5.9	300	465.9	41.9	39.2

nd = not detected

* Minimum and maximum values were calculated based on all samples, whereas means were calculated on detected values only.

Discussion

Fish are often highly mobile depending on species or life-history stage, and the area in which an individual is caught may only represent a tiny fraction of the geographic area in which it lives. For example, it has been previously reported that California scorpionfish tagged in Santa Monica Bay near Los Angeles have been recaptured as far south as the Coronado Islands in Mexico (Hartmann 1987, Love et al. 1987). Therefore, even though an individual fish may have been caught

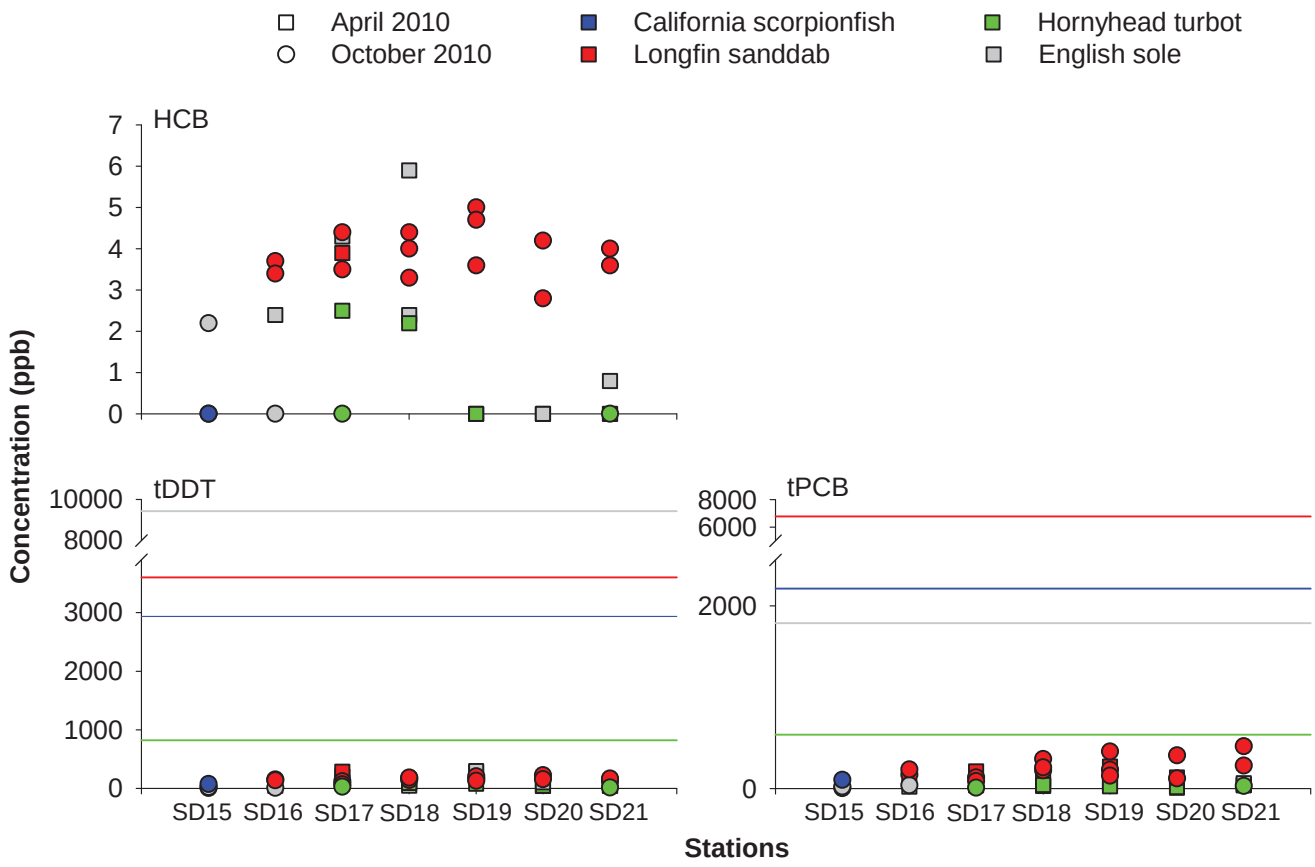

Figure 7.3

Concentrations of HCB, tDDT, and tPCBs in liver tissues of fishes collected from each SBOO trawl station during 2010. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for each species; HCB was not detected in tissue from these species during the pre-discharge period because of substantially higher detection limits; therefore, reference lines for this contaminant are absent. To differentiate between missing values (i.e., samples that were not collected or not analyzed; see Table 7.1) and non-detects, zeros were added as placeholders for non-detected values. Stations SD17 and SD18 are considered "nearfield" (see text).

near the South Bay outfall, any tissue contaminants it contains are likely bioaccumulated over a broad geographic area. It is therefore difficult to attribute the contaminant loading in the liver or muscle tissue of fishes collected in the SBOO region to discharge of wastewater from the outfall.

During 2010, several trace metals, the pesticides DDT and HCB, PAHs and PCBs were detected in liver tissue samples from four species of fish collected in the SBOO region. Many of the same metals, pesticides and PCBs were also detected in muscle tissues during the year, although often less frequently and/or in lower concentrations. Tissue contaminant values ranged widely within and among species and stations. However, all were within the range of values reported previously for the Southern California Bight (SCB) (Mearns et al. 1991, City of San Diego 1996–2001, Allen et al. 1998). In addition, while some muscle tissue samples from sport fish collected in the area exhibited concentrations of arsenic and selenium above the median international standard for shellfish, and some had concentrations of mercury and PCBs that exceeded OEHHA fish contaminant goals, concentrations of mercury and DDT were below USFDA human consumption limits.

The frequent occurrence of metals and chlorinated hydrocarbons in fish tissues are likely due to multiple factors. For instance, Mearns et al. (1991) described the distribution of several contaminants, including arsenic, mercury, DDT, and PCBs as being ubiquitous in the SCB, and not unique to

Table 7.4

Summary of metals in muscle tissues of fishes collected at SBOO rig fishing stations during 2010. Data include the number of detected values (*n*), minimum, maximum, and mean* detected concentrations for each species, and the detection rate and maximum value for all species. Concentrations are expressed as parts per million (ppm); the number of samples per species is indicated in parentheses. Bold values meet or exceed OEHHA fish contaminant goals, USFDA action limits, or median international standards (IS). See Appendix F.2 for MDLs and names for each metal represented by periodic table symbol.

	Al	Sb	As	Ba	Be	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Tl	Sn	Zn
Brown rockfish																		
n (out of 5)	2	0	5	0	0	0	1	5	0	0	0	5	0	5	0	3	2	5
Min	nd	nd	0.59	nd	nd	nd	nd	0.12	nd	nd	nd	0.08	nd	0.16	nd	nd	nd	2.4
Max	6.7	nd	1.22	nd	nd	nd	0.14	0.43	nd	nd	nd	**0.25**	nd	**0.32**	nd	0.66	0.23	4.8
Mean	6.3	—	0.91	—	—	—	0.14	0.31	—	—	—	0.17	—	0.23	—	0.51	0.22	3.5
California scorpionfish																		
n (out of 6)	3	0	6	1	1	0	3	6	3	0	0	6	0	6	0	4	2	6
Min	nd	nd	1.36	nd	nd	nd	nd	0.15	nd	nd	nd	0.10	nd	0.19	nd	nd	nd	2.8
Max	11.5	nd	**3.40**	0.06	0.01	nd	0.14	0.43	2.7	nd	nd	**0.40**	nd	**0.61**	nd	0.56	0.33	6.3
Mean	7.8	—	**2.45**	0.06	0.01	—	0.13	0.30	2.5	—	—	0.20	—	**0.35**	—	0.50	0.30	3.8
Mixed rockfish	1	0	1	0	0	0	0	1	0	1	0	1	0	1	0	0	0	1
n (out of 1)	10.9	nd	**1.50**	nd	nd	nd	nd	1.16	nd	0.21	nd	0.15	nd	**0.32**	nd	nd	nd	4.5
Min	10.9	nd	**1.50**	nd	nd	nd	nd	1.16	nd	0.21	nd	0.15	nd	**0.32**	nd	nd	nd	4.5
Max	10.9	—	**1.50**	—	—	—	—	1.16	—	0.21	—	0.15	—	**0.32**	—	—	—	4.5
Mean																		
All species:																		
Detection Rate (%)	50	0	100	8	8	0	33	100	25	8	0	100	0	100	0	58	33	100
Max Value	11.5	nd	**3.40**	0.06	0.01	nd	0.14	1.16	2.7	0.21	nd	**0.40**	nd	**0.61**	nd	0.66	0.33	6.3
OEHHA**	na	na	na	na	na	na	na	na	na	na	na	0.22	na	7.4	na	na	na	na
USFDA Action Limit***	na	na	na	na	na	na	na	na	na	na	na	1	na	na	na	na	na	na
Median IS***	na	na	1.4	na	na	na	1	20	na	na	na	0.5	na	0.3	na	na	175	70

na = not available; nd = not detected

* Minimum and maximum values were calculated based on all samples, whereas means were calculated on detected values only.

** From the California OEHHA (Klasing and Brodberg 2008).

*** From Mearns et al. 1991. USFDA mercury action limits and all international standards (IS) are for shellfish, but are often applied to fish.

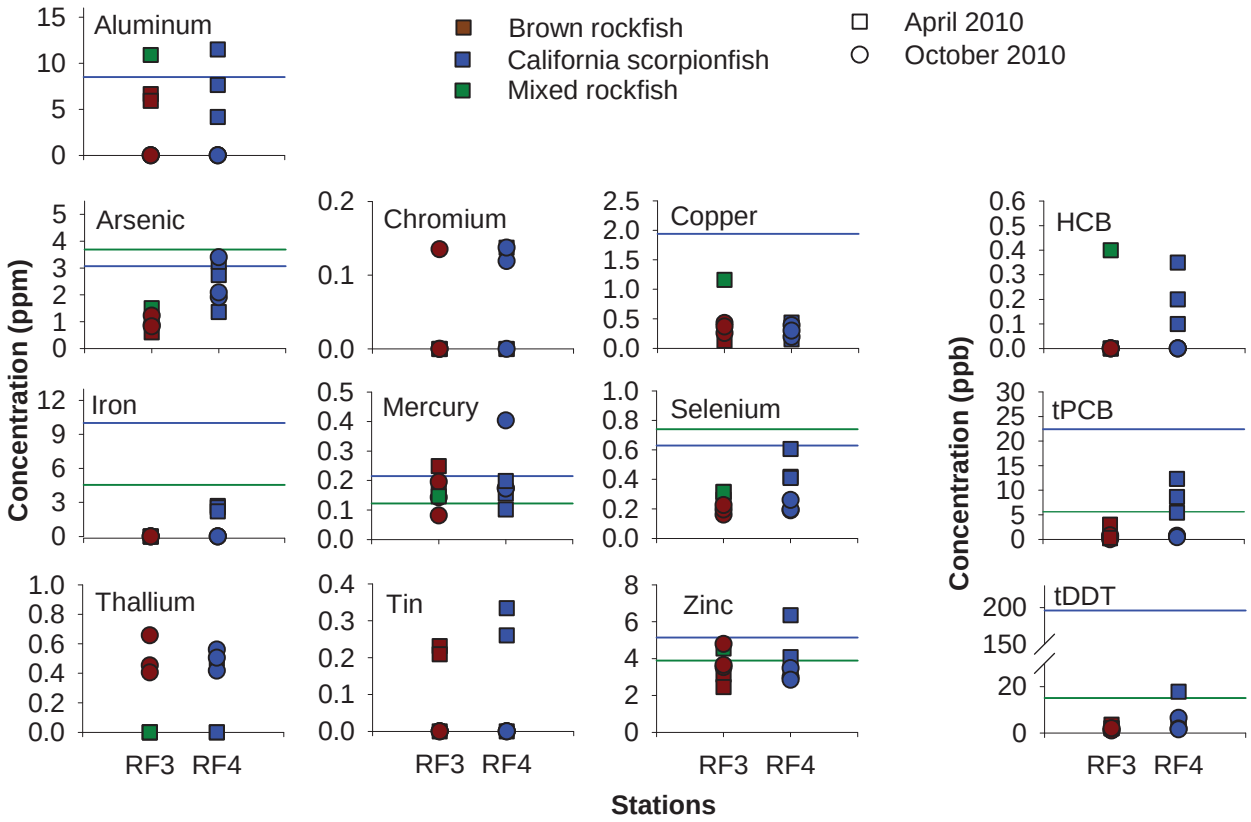

Figure 7.4

Concentrations of frequently detected metals, HCB, tDDT, and tPCB in muscle tissues of fishes collected from each SBOO rig fishing station during 2010. Reference lines are maximum values detected during the pre-discharge period (1995–1998) for California scorpionfish and mixed rockfish; brown rockfish were not collected during that period. All missing values = non-detects. Station RF3 is considered "nearfield" (see text).

the SBOO region. In fact, many metals occur naturally in the environment, although little information is available on background levels in fish tissues. Brown et al. (1986) determined that no areas of the SCB are sufficiently free of chemical contaminants to be considered reference sites. This has been supported by more recent work examining PCBs and DDTs (Allen et al. 1998, 2002). The lack of contaminant-free reference areas in the SCB clearly pertains to the South Bay outfall region, as demonstrated by the presence of many contaminants in fish tissues prior to wastewater discharge (City of San Diego 2000b).

In addition to distributional differences of contaminants in the environment, physiological accumulation and distribution of these contaminants differ among species or even among individuals from different life history stages of a single species (see Groce 2002 and references therein). For example, different species exposed to the same concentrations of a contaminant often differ in the amount of the contaminant that ends up in their tissues. Finally, exposure to contaminants can vary greatly between different species and among individuals of the same species depending on migration habits (Otway 1991). For example, fishes may be exposed to contaminants in an area that is highly contaminated and then migrate into an area that is not. This is of particular concern for fishes collected in the vicinity of the SBOO, as there are many point and non-point sources that may contribute to contamination in the region (see Chapters 2–4); some monitoring stations are located near the Tijuana River, San Diego Bay, and dredged materials disposal sites, and input from these sources may affect fish in surrounding areas.

Overall, there was no evidence that fishes collected in 2010 were contaminated by the discharge of wastewater from the SBOO. Although several individual tissue samples contained concentrations

Table 7.5

Summary of pesticides, tPCB, and lipids in muscle tissues of fishes collected at SBOO rig fishing stations during 2010. Data include the number of detected values (*n*), minimum, maximum, and mean* detected concentrations for each species and the detection rate and max value for all species. Data are expressed in ppb for all parameters except lipids, which are presented as % weight; the number of samples per species is indicated in parentheses. Bold values meet or exceed OEHHA fish contaminant goals, USFDA action limits, or median international standards (IS). See Appendix F.2 for MDLs and Appendix F.3 for values of individual constituents summed for tDDT and tPCB.

	Pesticides			
	HCB	**tDDT**	**tPCB**	**Lipids**
Brown rockfish				
n (out of 5)	0	5	4	5
Min	nd	1.0	nd	0.29
Max	nd	3.6	3.0	0.49
Mean	–	2.0	1.2	0.36
California scorpionfish				
n (out of 6)	3	6	6	6
Min	nd	1.5	0.4	0.24
Max	0.35	17.8	**12.3**	1.42
Mean	0.22	5.9	**4.7**	0.70
Mixed rockfish				
n (out of 1)	1	1	1	1
Min	0.40	2.0	0.2	0.55
Max	0.40	2.0	0.2	0.55
Mean	0.40	2.0	0.2	0.55
All Species:				
Detection Rate (%)	33	100	92	100
Max Value	0.40	17.80	**12.3**	1.42
OEHHA**	na	21	3.6	na
U.S. FDA Action Limit***	na	5000	na	na
Median IS***	na	5000	na	na

na = not available; nd = not detected

* Minimum and maximum values were calculated based on all samples, whereas means were calculated on detected values only.

** From the California OEHHA (Klasing and Brodberg 2008).

*** From Mearns et al. 1991. USFDA action limits and all international standards (IS) are for shellfish, but are often applied to fish.

of some metals that exceeded pre-discharge maxima, concentrations of most contaminants were not substantially different from pre-discharge levels (City of San Diego 2000b). In addition, most of the tissue samples that did exceed pre-discharge values were widely distributed among the sampled stations and showed no patterns that could be attributed to wastewater discharge. Finally, there was no other indication of poor fish health in the region, such as the presence of fin rot, other indicators of disease, or any physical anomalies (see Chapter 6).

Literature Cited

Allen, M.J., S.L. Moore, K.C. Schiff, D. Diener, S.B. Weisburg, J.K. Stull, A. Groce, E. Zeng, J. Mubarak, C.L. Tang, R. Gartman, and C.I. Haydock. (1998). Assessment of demersal fish and megabenthic invertebrate assemblages on the mainland shelf of Southern California in 1994. Southern California Coastal Water Research Project, Westminster, CA.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, S.A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. (2002). Southern California Bight 1998 Regional Monitoring Program: V. Demersal Fishes and Megabenthic Invertebrates. Southern California Coastal Water Research Project, Westminster, CA.

Brown, D.A., R.W. Gossett, G.P. Hershelman, C.G. Word, A.M. Westcott, and J.N. Cross. (1986). Municipal wastewater contamination in the Southern California Bight: Part I– metal and organic contaminants in sediments and organisms. Marine Environmental Research, 18: 291–310.

City of San Diego. (1996). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1995. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1997). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1996. City of San Diego Ocean

Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1998). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1997. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (1999). Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1998. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000a). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000b). Annual Receiving Waters Monitoring Report for the South Bay Ocean Outfall, 1999. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2000c). International Wastewater Treatment Plant Final Baseline Ocean Monitoring Report for the South Bay Ocean Outfall (1995–1998). City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2001). Annual Receiving Waters Monitoring Report for the Point Loma Ocean Outfall, 2000. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2004). Quality Assurance Manual, 2003. City of San Diego Ocean Monitoring Program, Metropolitan Wastewater Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

City of San Diego. (2011). 2010 Annual Reports and Summary: Point Loma Wastewater Treatment Plant and Point Loma Ocean Outfall. City of San Diego, Public Utilities Department, Environmental Monitoring and Technical Services Division, San Diego, CA.

Groce, A.K. (2002). Influence of life history and lipids on the bioaccumulation of organochlorines in demersal fishes. Master's thesis. San Diego State University. San Diego, CA.

Hartmann, A.R. (1987). Movement of scorpionfishes (Scorpaenidae: *Sebastes* and *Scorpaena*) in the Southern California Bight. California Fish and Game, 73: 68–79.

Klasing, S. and R. Brodberg (2008). Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. California Environmental Protection Agency, Office of Environmental Health Hazard Assessment, Sacramento, CA.

Lauenstein, G.G. and A.Y. Cantillo, eds. (1993). Sampling and Analytical Methods of the NOAA National Status and Trends Program National Benthic Surveillance and Mussel Watch Projects 1984–1992: Vol. I–IV. Technical Memorandum NOS ORCA 71. NOAA/NOS/ORCA, Silver Spring, MD.

Love, M.S., B. Axell, P. Morris, R. Collins, and A. Brooks. (1987). Life history and fishery of the California scorpionfish, *Scorpaena guttata*, within the Southern California Bight. Fisheries Bulletin, 85: 99–116.

Mearns, A.J., M. Matta, G. Shigenaka, D. MacDonald, M. Buchman, H. Harris,

J. Golas, and G. Lauenstein. (1991). Contaminant Trends in the Southern California Bight: Inventory and Assessment. NOAA Technical Memorandum NOS ORCA 62. Seattle, WA.

Otway, N. (1991). Bioaccumulation studies on fish: choice of species, sampling designs, problems and implications for environmental management. In: A.G. Miskiewicz (ed.). Proceedings of a Bioaccumulation Workshop: Assessment of the Distribution, Impacts, and Bioaccumulation of Contaminants in Aquatic Environments. Australian Marine Science Association, Inc./Water Board.

Rand, G.M., ed. (1995). Fundamentals of Aquatic Toxicology: Effects, Environmental Fate, and Risk Assessment. 2nd ed. Taylor and Francis, Washington, D.C.

Schiff, K. and M.J. Allen. (1997). Bioaccumulation of chlorinated hydrocarbons in livers of flatfishes from the Southern California Bight. In: S.B. Weisberg, C. Francisco, and D. Hallock (eds.). Southern California Coastal Water Research Project Annual Report 1995–1996. Southern California Coastal Water Research Project, Westminster, CA.

[USEPA] United States Environmental Protection Agency. (2000). Bioaccumulation Testing and Interpretation for the Purpose of Sediment Quality Assessment. Status and Needs. EPA-823-R-00-001. U.S. Environmental Protection Agency.